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An investigation of the effects of harvesting time and milling moisture content of paddy on the quality of milled rice

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Key words: paddy, rice, breakage, cracked ratio, milling quality.

Abbreviations: paddy harvest time (PHT), moisture content at milling process (MCMP), milled rice breakage (MRB), ratio of cracked kernels (RCK), days after fifty percent flowering (DAFPF).

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Abstract

Paddy harvest time (PHT) and its moisture content at milling process (MCMP) are two major factors determining the milling quality of rice. In this regards, a field research was conducted to study the effect of these factors on milled rice breakage (MRB) and ratio of cracked kernels (RCK) of Hashemi paddy cultivar in north of Iran. Five harvest times of 24, 27, 30, 33, 36 days after fifty percent flowering (DAFPF) and four milling moisture contents of 8-9, 10-11, 12-13, and 14-15% dry basis (d.b.) were considered for the research. Results showed that the effects of PHT and MCMP were significant on the MRB and RCK (P < 0.01). The lowest (16.32%) MRB was recorded at 30 DAFPF; however there was no significant difference between values at 27 and 30 DAFPF (17.02 and 16.32%, respectively). Results also indicated that the lowest (9.84%) MRB mean was obtained at 8-9% d.b. of MCMP. The least (1.813%) RCK was obtained at 27 DAFPF; however there was no significant difference between the RCK at 27 and 30 DAFPF (1.813 and 1.750%, respectively). Besides, the lowest mean values of RCK (1.048 and 1.288%) were determined at 8-9 and 10-11% MCMP. As a final conclusion, in order to gain the least MRB and RCK, the most suitable situations for harvesting and milling the 'Hashemi' cultivar in north of Iran were determined to be harvesting at 30 DAFPF and milling at PMC of 8-9% d.b.

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Introduction

Rice (*Oryza sativa* L.) as the second important cereal crop feeds more than half of the world people (Jittanit *et al*., 2010; FAO, 2004). In the developing world, 27% of dietary energy and 20% of dietary protein are supplied by the rice. Rice is the main source of income for more than 100 million households in Asia and Africa (FAO, 2004). Its kernel breakage during milling process is a major concern in rice producing countries. As a common rule, milled rice kernel longer than 75% of a whole kernel is known as head rice; otherwise identified as broken kernel (Thakur and Gupta, 2006). Usually, the price of broken milled rice is only 30 to 50% of the price of head milled rice (Ntanos *et al.,* 1996). Less mechanical resistance of rice kernels in milling operation is the key factor for milled rice breakage. Milling is the last stage of milled rice production activities. During this process, a lot of mechanical and thermal stresses are applied to the rice grains. So, some of weak kernels are easily broken (Afzalinia *et al.,* 2004). Milling the rice is an industrial operation which can easily be controlled by right settings the milling machines; so the problems related to milling process, mostly is determined by the history of the paddy before milling stage (Lantin, 1999). Immature, chalky, fissured, too moist, and too dry grains usually are more susceptible to breakage in milling stage (Matthews *et al.,* 1970; Farouk and Islam, 1995). All of these are known as pre-milling factors. Among them, the harvest time is a more reported problem. Too early or too late harvesting of rice leads to arise the more immature or cracked kernels, thus resulting in more broken milled rice. Research of Ntanos *et al.* (1996) indicated that there was an optimum harvest time for each rice cultivar to obtain the highest total milling yield with the lowest milled rice breakage. Hossain *et al.* (2009) concluded that the suitable harvest time for higher head rice yield of three aromatic rice cultivars of Bangladesh was 30 to 35 days after flowering (DAF). Sürek and Beşer (1998) showed that the minimum milled rice breakage was obtained at 49 DAF in Turkey. Malik *et al.* (1981) studied the effects of harvest time and drying methods on milling quality of rice. Maximum head rice recovery for Basmati 370 and IR 6-945 cultivars were achieved at 34 DAF and for Basmati 198 cultivar was attained at 40 DAF. Siebenmorgen *et al.,* (2006) also determined the proper harvest time of rice in form of the paddy moisture level at harvesting time. They concluded that the general range of suitable harvest moisture content of rice in order to attain the maximum HRY, changed from 19 to 22% and 22 to 24% for long and medium grain cultivars, respectively. Truong (2007) declared that harvesting the rice a few days before maturity had not much impact on the kernel fissuring, but delays in harvest time resulted in significant rice kernels fissuring (up to 24% of total brown rice), depending on the paddy cultivar.

Moreover, review of reports revealed that the paddy moisture content at milling process had a profound influence on the milling quality of rice. Too dry or too moist rice grains are more susceptible to breakage in milling machines and then the broken rice increases seriously. The quality of milled rice is low when paddy is hulled at high moisture content (Stipe, *et al.,* 1971). Pominski *et al.* (1961) revealed that the head rice yield of Bluebonnet-50 long-grain variety increased 3% for each one percent decrease in rice moisture in a range of 10 to 14%. Ancheta and Andales (1990) also concluded that the higher values of HRY were obtained at less moisture content of 12% w.b. In the study of Juma Omar and Yamashita (1987), the average breakage percent of milled rice increased as rough rice moisture content increased from 8-13% in a commercial rubber roll huller (Satake Co. Ltd, Japan).

Review of a lot of studies showed that no research was conducted on the combined effect of paddy harvest time and its milling stage's moisture content on milling quality of rice. So, in this research, the effects of five levels of harvest time and four milling moisture levels of long grain paddy variety of Hashemi were studied on milled rice breakage and crack percent in north of Iran.

Materials and methods

This research was conducted at the rice research institute of Iran (RRII). A randomized complete block design (RCBD) with two independent variables (paddy harvest time (PHT) and milling moisture content at milling process (MCMP)) in four replications was considered for the experiment. Five levels PHT of 24 , 27, 30, 33, 36 days after fifty percent flowering (DAFPF) and four paddy moisture content at milling (MCMP) of 8-9, 10-11, 12-13, and 14-15% dry basis (d.b.) were selected for the research. Long-grain rice cultivar of Hashemi as the common paddy cultivar in North of Iran was chosen for the study.

Field operations and preliminary laboratory processes

Four experimental plots in sizes of 3×15 m² were prepared for all replications and then randomly named as R1, R2, R3, and R4. Then each plot was divided into five sub-plots and named randomly as H1, H2, H3, H4, and H5 for five levels of harvesting time.

Plowing and puddling operations were performed manually. Rice seedlings were transplanted by hand at intervals of 20 cm × 20 cm. At each harvest time, the crop were harvested by hand and then threshed by a suitable motorized paddy thresher. Subsequently, the threshed paddy was cleaned by a proper cleaner (SATAKE Co. Ltd, Japan). Then the clean paddy was divided into four batches of 250 g and each lot was dried up to any of four experimental moisture levels by a laboratory drier (Memmart Model 600, Germany) at 45° temperature.

For each treatment, two hundred grams of dried paddy was kept in a plastic bag for the next operations. Then the dried paddy was husked by a laboratory rubber roll huller (SATAKE Co. Ltd, Japan). Subsequently, the brown rice was whitened by a laboratory friction-type whitener (McGill Miller, USA).

Determining the breakage percent of milled rice (MRB)

Each milled rice sample was weighed by a laboratory scale with an accuracy of 0.01 g and then separated into broken and whole milled rice kernels by the laboratory rice rotary sieve (SATAKE TRG058, Japan). Because of incomplete action of the separator device, hand sorting completed the application. Then the broken and head rice portions were weighed and the values were recorded. Breakage percent of milled rice (MRB) was determined as the mass ratio of broken milled rice to the total milled rice times 100 (Farouk and Islam, 1995).

Determining the ratio of the cracked kernels (RCK)

For each sample, hundred paddy grains were manually husked and next, the cracked brown rice kernels counted by a light kernel crack detector. The ratio of the number of cracked kernels to the total number of 100 was recorded as the ratio of the cracked kernels (RCK).

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using the statistical software of MSTATC. Variable means found to be significant were compared using the fisher's protected LSD at 1% or 5% level of probability.

Results and discussion

Results of the ANOVA indicated that there were significant (P < 0.01) effects of PHT and MCMP on MRB and RCK (Table 1). The interaction effect of PHT×MCMP was not significant, demonstrating that MRB and RCK at any PHT had similar trends with respect to the variation of MCMP.

Milled rice breakage (MRB)

Table 2 shows that the least (16.32%) MRB was obtained at the 3rd harvest time (30 DAFPF). However, there was no significant difference between MRB values at 2nd and 3rd harvest times (17.02 and 16.32%, respectively). Also, the highest values of MRB were recorded at the first (24 DAFPF) and last (36 DAFPF) harvest times (21.30 and 22.73%), respectively. Higher records of broken milled rice at first harvest time can be contributed to increasing of the number of thin and immature kernels. Thin immature rice kernels often break during milling process (Siebenmorgen, *et al.*, 2006). The higher values of broken milled rice at the last harvest times can also be related to the increasing the number of RCK (Ntanos *et al.*, 1996).

Table 1. Mean squares of ANOVA for milled rice breakage percent and cracked kernels percent as affected by harvest time and paddy milling moisture content.

Source	df	Mean of squares (MS)	
		Milled rice breakage (%)	Cracked kernels (%)
R	3		
Harvest time (HT)	4	130.576 **	0.899 **
Paddy moisture content (PMMC)	3	2829.322 **	27.627 **
HT×PMMC	12	12.598 ns	0.138 ns
Error	57	13.273	0.137
C.V.		18.25%	18.77%

** Significant at the 0.01probability level.
ns, not significant.

Similar trends were observed in some studies. In the study of Bautista *et al.* (2009), the head rice yield or breakage percent increased up to a peak value and then decreased with delay in harvest time. Sürek and Beşer (1998) also reported that the MRB decreased at first; then did not significantly vary and at last increased. However, in the study of Ntanos *et al.* (1996), an increasing trend in MRB rice with more delays in PHT time was reported.

Table 3 also shows that there was a significant difference between the MRB at different MCMPs. So, the MRB decreased with decrease in MCMP. This result can be contributed to the increasing the mechanical strength of paddy grains in lower MCMPs and then higher resistance against the forces developed in hulling and milling machines. The bending strength of rice grains was inversely related to grain moisture content (Ancheta and Andales, 1990). The decreasing trend of MRB with respect to the decrease in MCMP was also reported in some researches (Stipe, *et al.,* 1971; Juma Omar and Yamashita,1987). However Dilday (1987) obtained an opposite result compared to the other researches. In his study, the MRB decreased with increase of paddy moisture content in a range of 12 to 16%.

Table 2. Breakage and cracked kernels percents at different levels of harvest time. Means are averaged over four paddy milling moisture content.

Harvest time	Paddy moisture content at harvest time (%)	Milled rice breakage (%)	Cracked kernels (%)
1st HT	22.97	21.30^{a}	1.844^{ab}
2nd HT	20.88	17.02^{b}	1.813^{c}
3rd HT	17.92	16.32^{b}	1.750^{c}
4th HT	16.34	21.22^{a}	2.172^{ab}
5th HT	15.28	22.73^{a}	2.278^{a}

Means of each column followed by the same letter in the same column are not significantly different at $P \leq 0.01$.

Ratio of cracked kernels (RCK)

Table 2 shows that the RCK also decreased at first and then significantly increased. Like the case of MRB, fissure or crack in rice kernels can be originated from stresses developing in milling equipments. Thus, fissuring the soft and thin green paddy grains at early ripening stages in milling process can be a rational phenomenon. As shown in table 2, the minimum RCK was occurred at 2nd harvest time (27 DAFPF); however there was no significant difference between RCK at 2nd and 3rd harvest times (27 and 30 DAFPF). Then RCK significantly increased at the last harvest times (33 and 36 DAFPF).

Also table 3 shows the significant differences between RCKs at different MCMPs (*P*< 0.01). Based on the information of this table, the least (1.048%) RCK were occurred at first MCMP (8-9%, d,b.). However, there was no significant difference between mean values of RCK at first and second MCMPs (1.048 and 1.288%, respectively). Also the RCK increased at later PHTs. The highest value (3.650%) was measured at the highest MCMP of 14-15%. This can be related to the less strength of paddy grains at moist conditions.

Table 3. Breakage and cracked kernels percents at different levels of milling stage's paddy moisture content. Means are averaged over five harvest times.

Paddy Milling moisture content, d.b. (%)	Milled rice breakage (%)	Cracked kernels (%)
8-9	9.84[a]	1.048[a]
10-11	14.09[b]	1.288[a]
12-13	19.40[c]	1.900[b]
14-15	36.53[d]	3.650[c]

Means of each column followed by the same letter in the same column are not significantly different at P ≤ 0.01.

Conclusions

It was concluded that the milled rice breakage and cracked kernels ratio of 'Hashemi' cultivar in north of Iran at early and late harvesting dates significantly increased. The least kernel damages in terms of milled rice breakage and fissure occurred at 30 DAFPF and MCMP of 8-9%.

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